

## APPENDIX F: KLAMATH NETWORK WATER QUALITY PHASE I REPORT

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Skull Cave front ice floor, Lava Beds National Monument 1968

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*"Man was not born to solve the problem of the universe, but rather to seek to lay bare the heart of the problem..."-Johann Wolfgang von Goethe*

#### **ABSTRACT**

Although the Klamath Network Water Quality Monitoring Program is intended to be closely integrated with the larger Vital Signs Monitoring Program, it is coordinated and funded separately. Therefore, we have prepared this report to be a relatively freestanding document for those interested in the water quality issues of the Klamath Network. This document facilitates the water quality monitoring plan development process by identifying potential watersheds to be monitored, describing the status of existing data, and reviewing current issues and priorities. Primary Klamath Network issues include adjacent land use . Agricultural operations, such as dairy and beef cattle ranching, farming, viniculture, , silviculture/timber harvest may result in road building, erosion, herbicide spraying, and sedimentation). Mariculture, visitor/recreational use (beaches, stable operations, boating, camping, park tours ), and water supply (water quality/quantity, flooding, overwithdrawal are additional concerns. Primary network needs include data analysis and feedback, and prioritization of management strategies, based on data analysis. Work within Klamath Network parks is underway to address these issues and needs.

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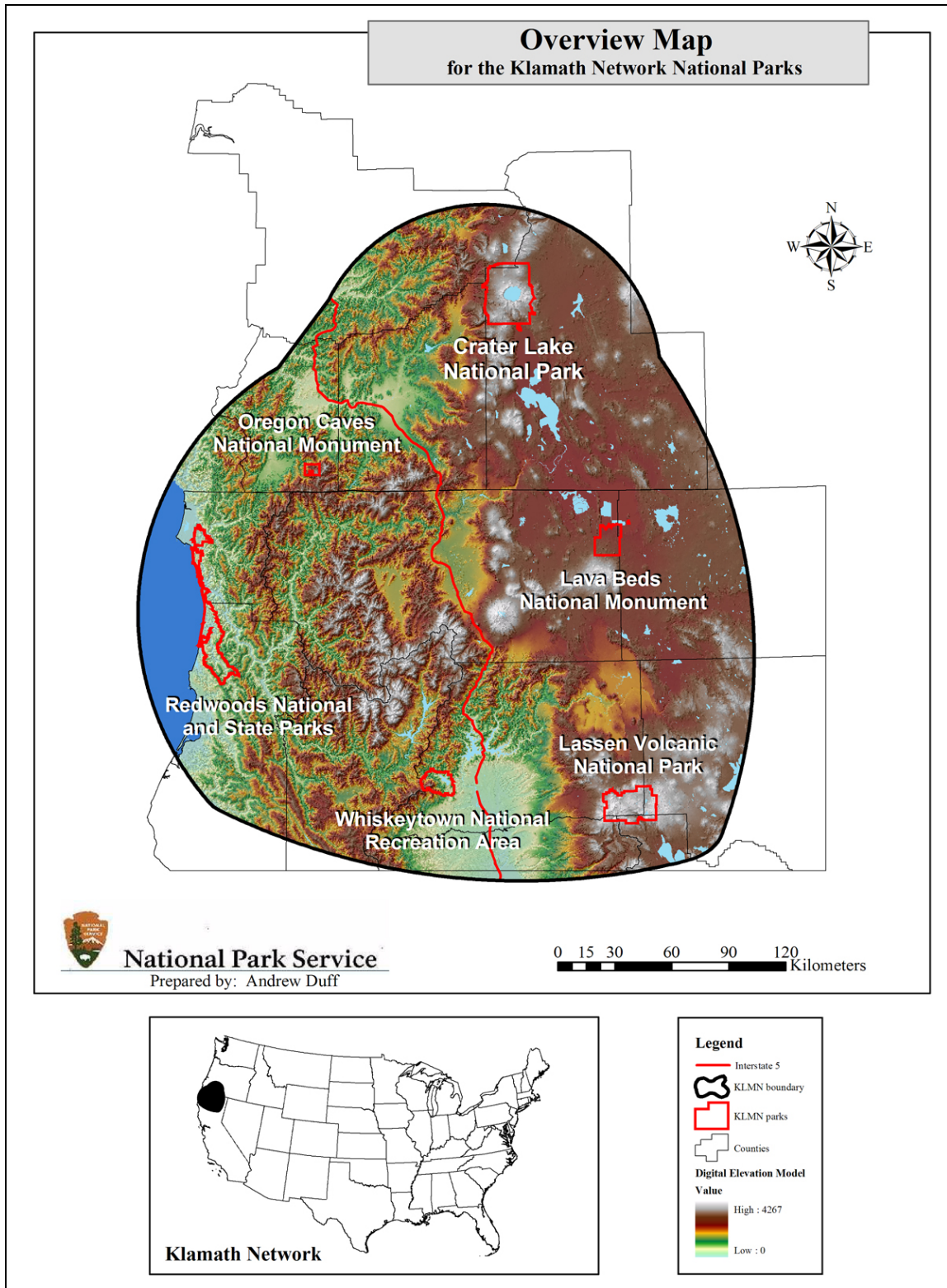
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**Figure 1.** Horseshoe Lake, Lassen Volcanic National Park

## **1.1. INTRODUCTION**

The Klamath Network Water Quality Report is intended to provide a broad overview of the aquatic resources within the parks. This report begins with an overview of aquatic resources of the Klamath Network and then describes allied research by other oversight agencies. Then we present a section for each of the individual park units and their resources, background information, and concerns, the report looks at common themes in inventory and monitoring and, finally, the process of determining vital signs.



**Figure 2.** General Overview of Klamath Network and the park units

## 1.2. OVERVIEW OF AQUATIC RESOURCES

Spanning a rugged region of exceptional climatic, topographic, and geologic complexity, the aquatic resources within the Klamath Network parks are many and varied. From west to east, Redwood National and State Parks has over 60 kilometers of coastal marine habitat, also extending 0.42 km (0.25 miles) offshore. The Park's freshwater resources include Redwood and Mill Creeks and their watersheds, coastal estuaries and lagoons, and slope fens and seeps. Oregon Caves National Monument is a small park unit with only one stream that starts within the main cave and runs out through the park, yet it also has wet meadows and seeps in the upper canyon. Parts of the creek are directly affected by visitors touring the cave. Whiskeytown National Recreation Area principally contains a large reservoir impounding Clear Creek, with many perennial and intermittent tributary streams. Historically, mining was a common enterprise within Whiskeytown, and as a result acid mine drainage and Mercury are of major concern. The park also contains the only known global population of Howell's alkali grass (*Puccinellia howellii*), which is restricted to a mesosaline fen in the park. Crater Lake National Park has the seventh deepest and the clearest caldera lake in the world. In addition, Crater Lake contains deep lake thermal areas and several important wetland areas. Lassen Volcanic National Park includes the largest concentration of freshwater lentic systems within our network parks, with over 250 lakes and ponds (many of which have never been inventoried), as well as several major stream drainages, geothermal areas, and sphagnum bogs along lake margins. Lava Beds National Monument has no surface water within its park boundaries, but is bounded on the north by Tule Lake. However, the park has approximately 28 known ice caves that are an important aquatic resource for wildlife and historically for human use. Table 1.2 in Chapter 1 summarizes the abundance of several common aquatic ecosystems in the Klamath Network parks. These ecosystems support many of the species of special interest described in Appendix E.

### A. Significant Waters

There are no designated Outstanding Resource Waters (ORW) within the Klamath Network at this time. However, Klamath Network and Crater Lake staff are in the process of obtaining ORW designation for Crater Lake from the Oregon Department of Environmental Quality.



The North Coast Regional Water Quality Control Board has identified Redwood National Park as a State Water Quality Protection Area, designated by the California State Water Board.



#### *Clean Water Act Section 303d Impaired Waters*

There are four listed 303d impaired waters within the Klamath Network. Two of these are located within Redwood (Redwood Creek and the Klamath River) as the result of adjacent upstream land use practices, in particular, the road building and reduced land cover associated with logging. There are two 303d waters in Whiskeytown: Willow Creek (associated with past mining activities) and the designated swim beaches.

Whiskeytown Staff are in the process of having the swim beaches delisted from the 303d list of impaired waters.

Table 1. 303d impaired waters within the Klamath Network.

<b>303d Impaired Water</b>	<b>Pollutant/Stressor</b>	<b>TMDL Priority<sup>*</sup></b>
Klamath River (Redwood)	Temperature	High
	Nutrients	High
Redwood Creek (Redwood)	Temperature	Low
	Sedimentation/Siltation	Medium
Willow Creek (Whiskeytown)	Metals	Low
Swim Beaches (Whiskeytown)	Bacteria	Low

### **1.3. ALLIED RESEARCH AND MONITORING PROGRAMS RELEVANT TO WATER QUALITY MONITORING IN THE KLAMATH NETWORK PARKS**

This section describes several ongoing research or monitoring programs that may provide funding, protocols, or partnership opportunities for the Klamath Network as it develops its water quality monitoring program.

#### **A. Relevant Aquatic Research and Monitoring Programs**

*U.S. Environmental Protection Agency (US EPA), Environmental Monitoring and Assessment Program (EMAP) - Surface Waters - Western Pilot Study.*

US EPA (with collaborators). Project Dates: 2000 - 2005.

The Western Pilot study is the Surface Waters component of the U.S. Environmental Protection Agency's (EPA) Western Geographic Study through the Environmental Monitoring and Assessment Program (EMAP). Its objective is to develop monitoring tools to estimate the ecological condition of surface waters across a large geographic area of the Western U.S. Its goal is to answer questions about the importance of stressors and the extent of their effects on ecological condition of wadeable streams. Methodology of the project includes sampling of water chemistry, stream discharge, periphyton, sediment, benthic macroinvertebrates, fish, and physical habitat characteristics.

Contact: David Peck. US EPA, Corvallis, OR. Phone: 541-754-4426, E-mail: peck.david@epa.gov.

*U.S. Environmental Protection Agency (US EPA), Environmental Monitoring and Assessment Program (EMAP) – National Coastal Assessment.*

US EPA (with collaborators). Project Dates: 1990 - 2003.

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\* See the EPA web site: <http://www.epa.gov/owow/tmdl/> for a description of the TMDL process.

EPA's National Coastal assessment conducted estuarine monitoring in all 23 coastal States and Puerto Rico, accounting for 99.8% of estuarine acreage in the continental U.S. and Puerto Rico. Data from several regional and national programs conducted by NOAA, USGS and the USFWS are included in the assessment of coastal condition. Assessment of the west coast was in 1999 and 2000 and extended in 2003 to cover the continental shelf. Marine biota (plankton, benthos, and fish) and environmental stressors (water quality, sediment quality and tissue bioaccumulation) were sampled.

Website link to access to the first and second Coastal Assessment Reports:

<http://www.epa.gov/owow/oceans/nccr2/index.html>.

Contact: J. Kevin Summers. US EPA. (850) 934-9201, summers.kevin@epamail.epa.gov.

*National Oceanic and Atmospheric Administration (NOAA) (with Western Regional Climate Center (Desert Research Institute)). Climate Reference Network.*

Project Dates: being implemented now (2004).

The Climate Reference Network is a network of climate stations being established, with the help of the Western Regional Climate Center, as part of a NOAA initiative. The goal of this project is to monitor long-term precipitation and temperature observations to investigate present and future climate change. If fully implemented, the network will have about 250 sampling stations nationwide. Many of these stations are being established in National Parks.

Contact: John Jensen, Program Manager. NOAA. Phone: 828-271-4475, E-mail: John.A.Jensen@noaa.gov.

*U.S. Geological Survey (USGS), Amphibian Research and Monitoring Initiative (ARMI).* USGS (with NPS, FWS, BLM). Project Dates: 2000 - ongoing.

In response to growing awareness of amphibian declines and malformations, the USGS Amphibian Research and Monitoring Initiative program (ARMI) was initiated by the United States Congress in 2000 to monitor trends in amphibian populations on Department of Interior (DOI) lands, and to research the cause of amphibian declines. While intensive monitoring will be focused on DOI lands, ARMI will also provide a framework for incorporating amphibian monitoring data by other agencies outside of DOI lands. Partnerships with other DOI agencies include a nationwide survey by the Fish and Wildlife Service on 48 National Wildlife Refuges in 31 states for contaminants that may induce malformations in amphibians.

Contact: Mike Adams, Wildlife Biologist. USGS Forest and Rangeland Ecosystem Science Center (FRES) Corvallis, OR. Phone: 541-758-8857, E-mail: Michael\_adams@usgs.gov.

## **B. Water Quality**

*U.S. Geological Survey (USGS), National Water Quality Assessment Program (NAWQA)*  
– *Sacramento River Basin Study.*

USGS. Project Dates: 1994 - 1998.

Initiated in 1994 and completed in 1998, the Sacramento River NAWQA, which covers the nearly 75,000 sq. km. (27,000 sq. mi.) drainage basin, is the largest within the state, with approximately a third of the total state runoff. The study was divided into 5 physiographic provinces: the Sacramento Valley, the Sierra Nevada, the Coast Ranges, the Cascade Range and the Modoc Plateau. The major use of water is agricultural (58%), environmental (32%), urban (6%), and other (4%). A suite of water quality parameters were measured including temperature, pH, dissolved oxygen, specific conductance, major cations and anions, metals, suspended sediment, bed sediment and fish tissue samples, and discharge. The major issues within the basin are elevated concentrations of trace metals, especially from abandoned mines (Whiskeytown); pesticide contamination of surface water and potential contamination of ground water (Lava Beds, Lassen, Whiskeytown); nitrate contamination of ground water (Lava Beds, Lassen, Whiskeytown), and urban runoff and volatile-organic-chemical contamination.

Contact: Joseph Domagalski. USGS. Sacramento, CA. Phone: 916-278-3077,  
E-mail: [joed@usgs.gov](mailto:joed@usgs.gov).

### **C. Water Quantity**

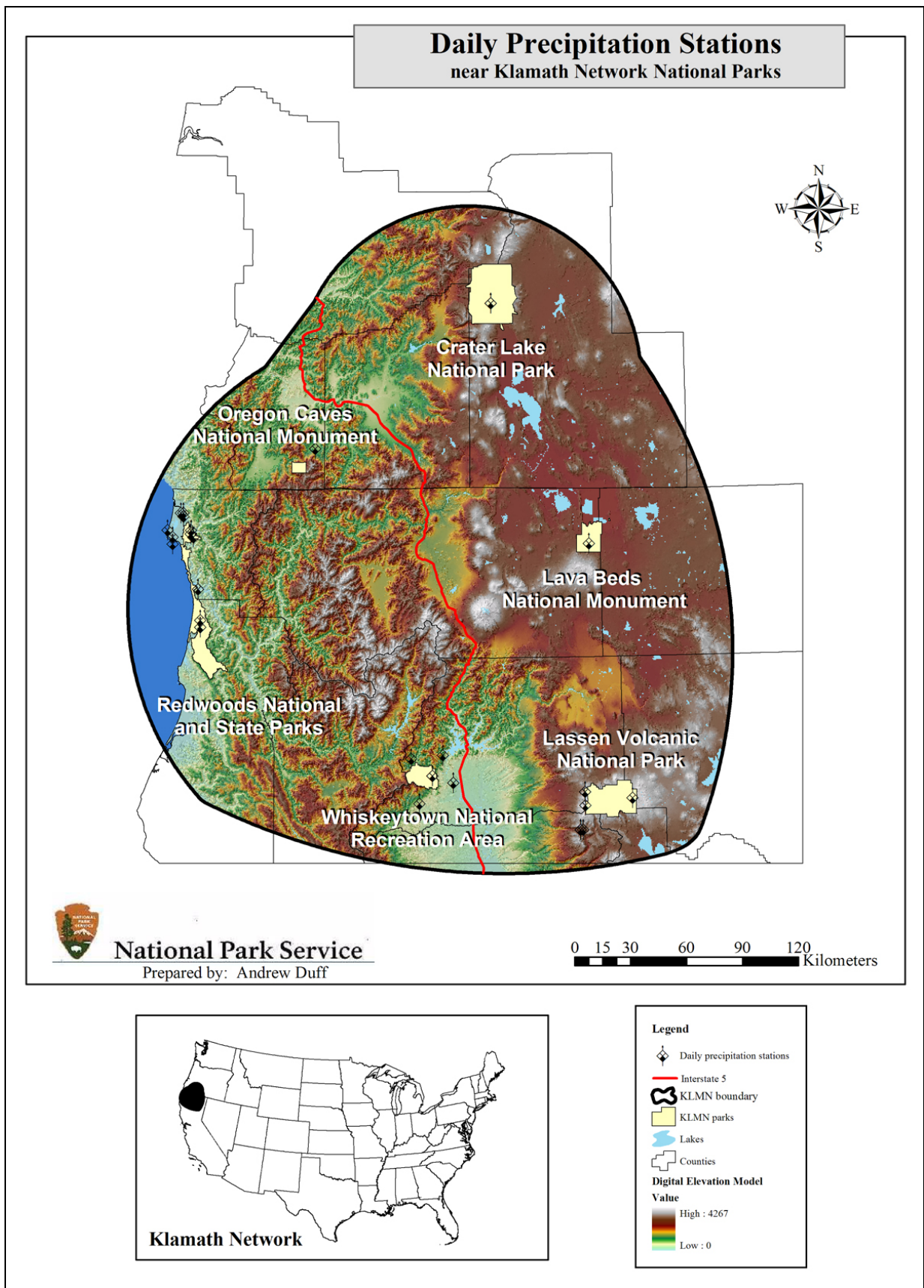
*U.S. Geological Survey (USGS), National Streamgaging Program (NSP).*  
USGS (with federal, state, and local agencies). Project Dates: variable/ongoing.

The USGS has been collecting streamflow information since 1887. Their National Streamgaging Program, which partners with many agencies, monitors flows on major and minor streams at nearly 7,000 stations throughout the United States. Streamflow gauging stations provide data that can be used for planning and operating water resources projects, flood warning, reservoir operations, and long term background information about changes in streamflow in response to climate and land use change.

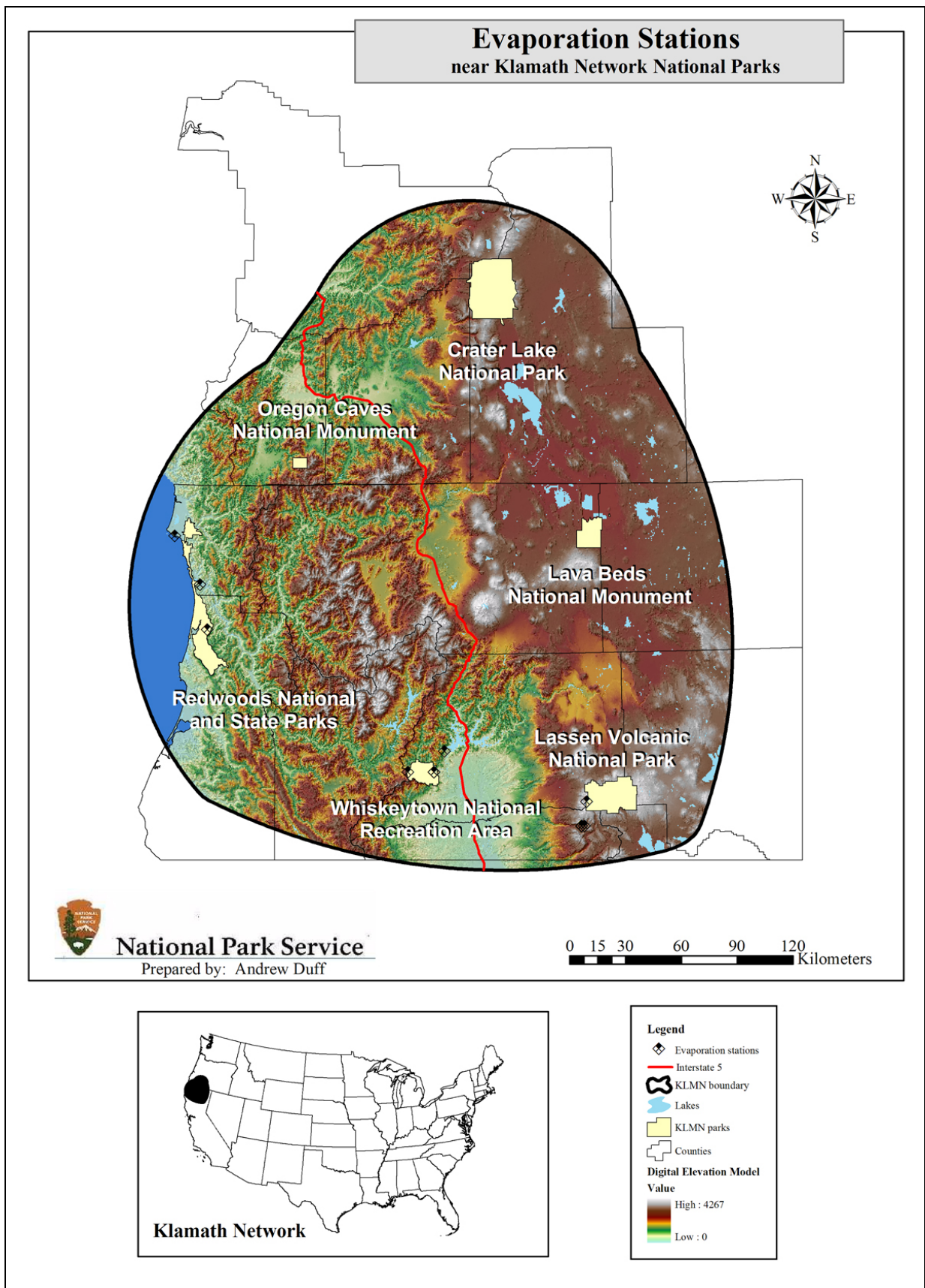
Contact: Mike Norris. USGS, Phone: 703 648-5304, E-mail: [mnorris@usgs.gov](mailto:mnorris@usgs.gov).

### **1.4. LOCATIONS OF ACTIVE MONITORING STATIONS IN THE KLAMATH NETWORK PARKS AND REGION**

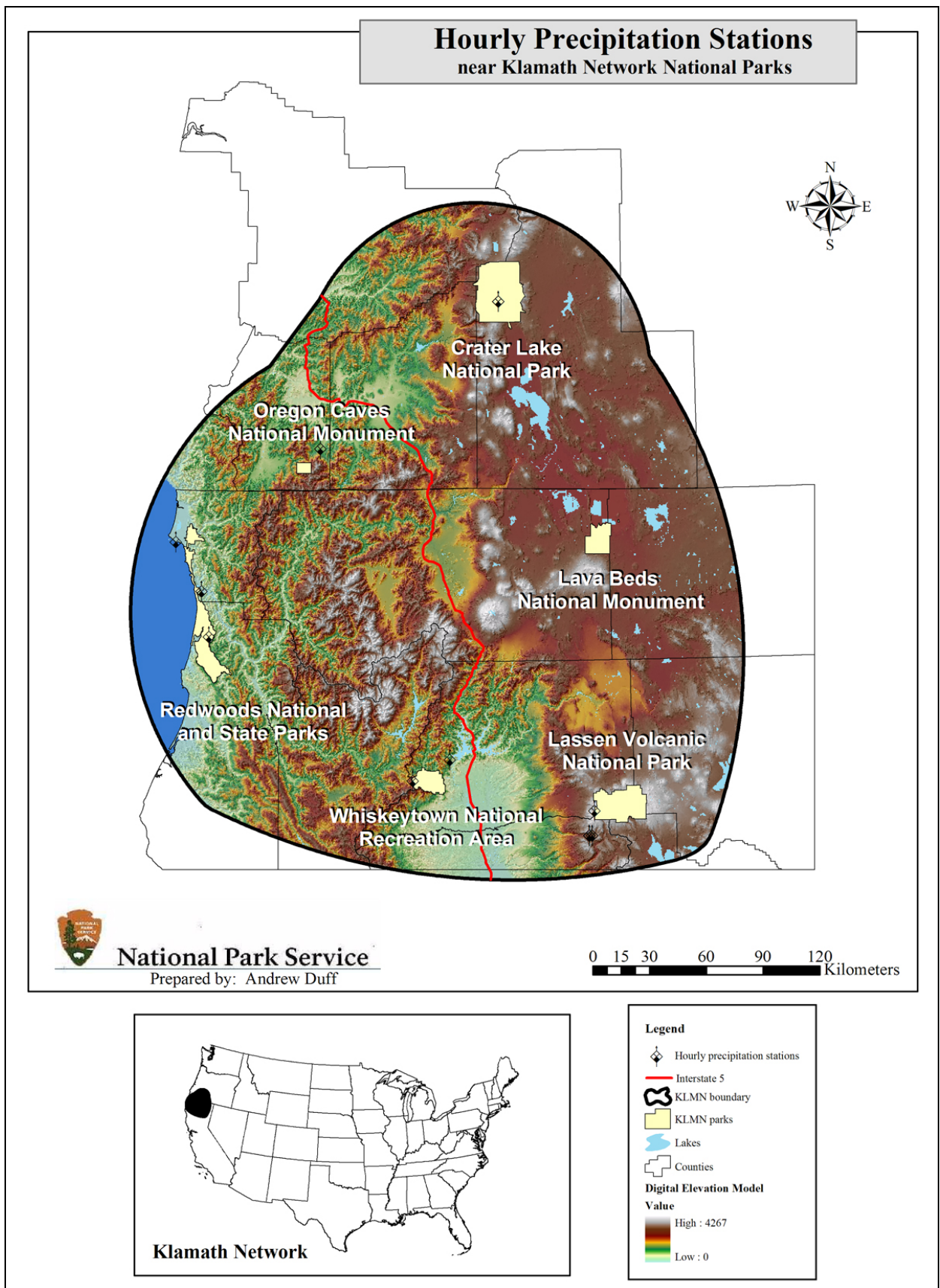
The following maps show the locations of georeferenced climatic, hydrologic, and water quality monitoring sites in Klamath Network parks. The network will emphasize verifying and georeferencing additional locations in the upcoming year, and will link spatial files with corresponding tabular records in the Dataset Catalog.



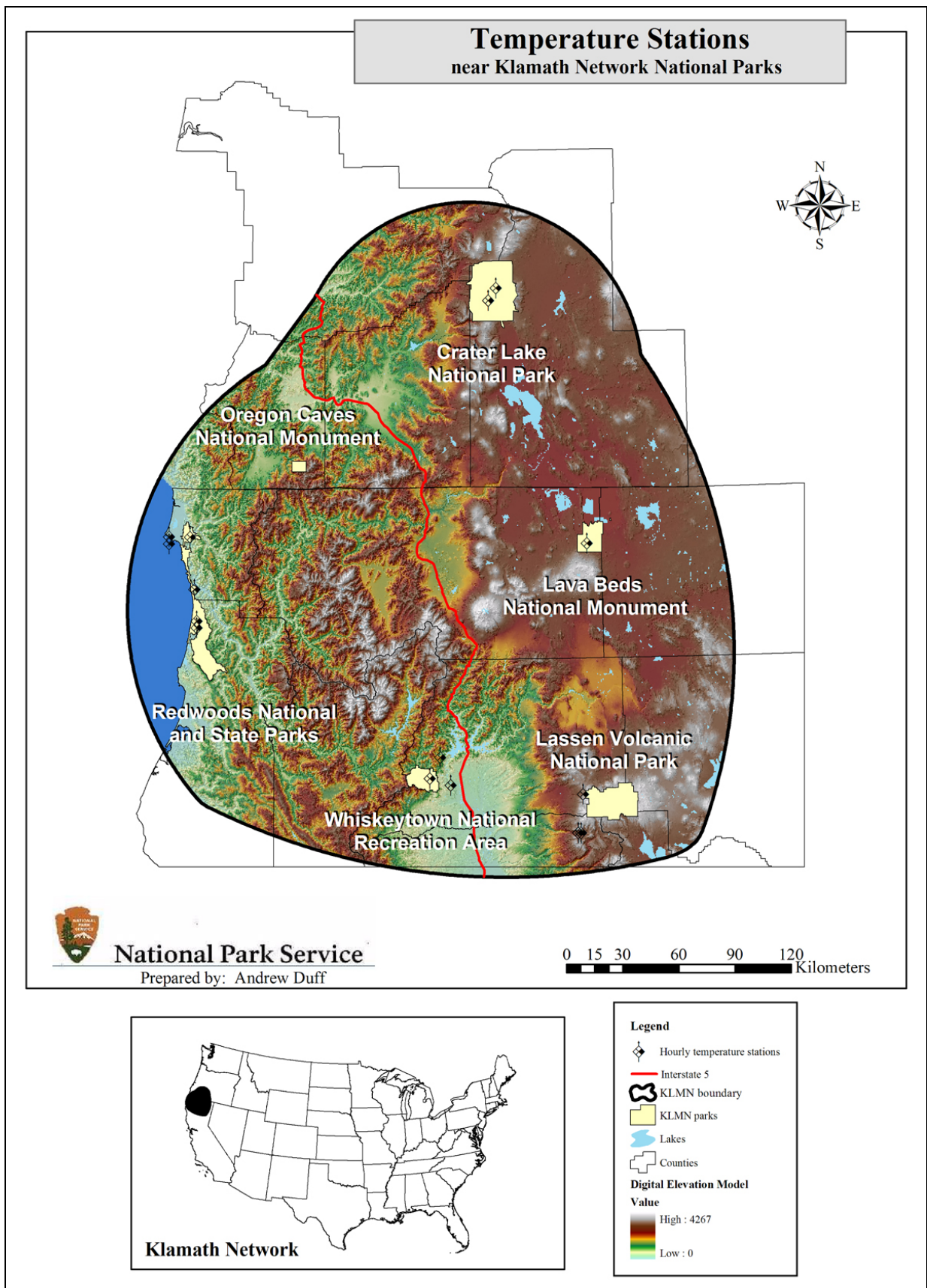
**Figure 3.** Daily Precipitation Stations in and around the Klamath Network parks.



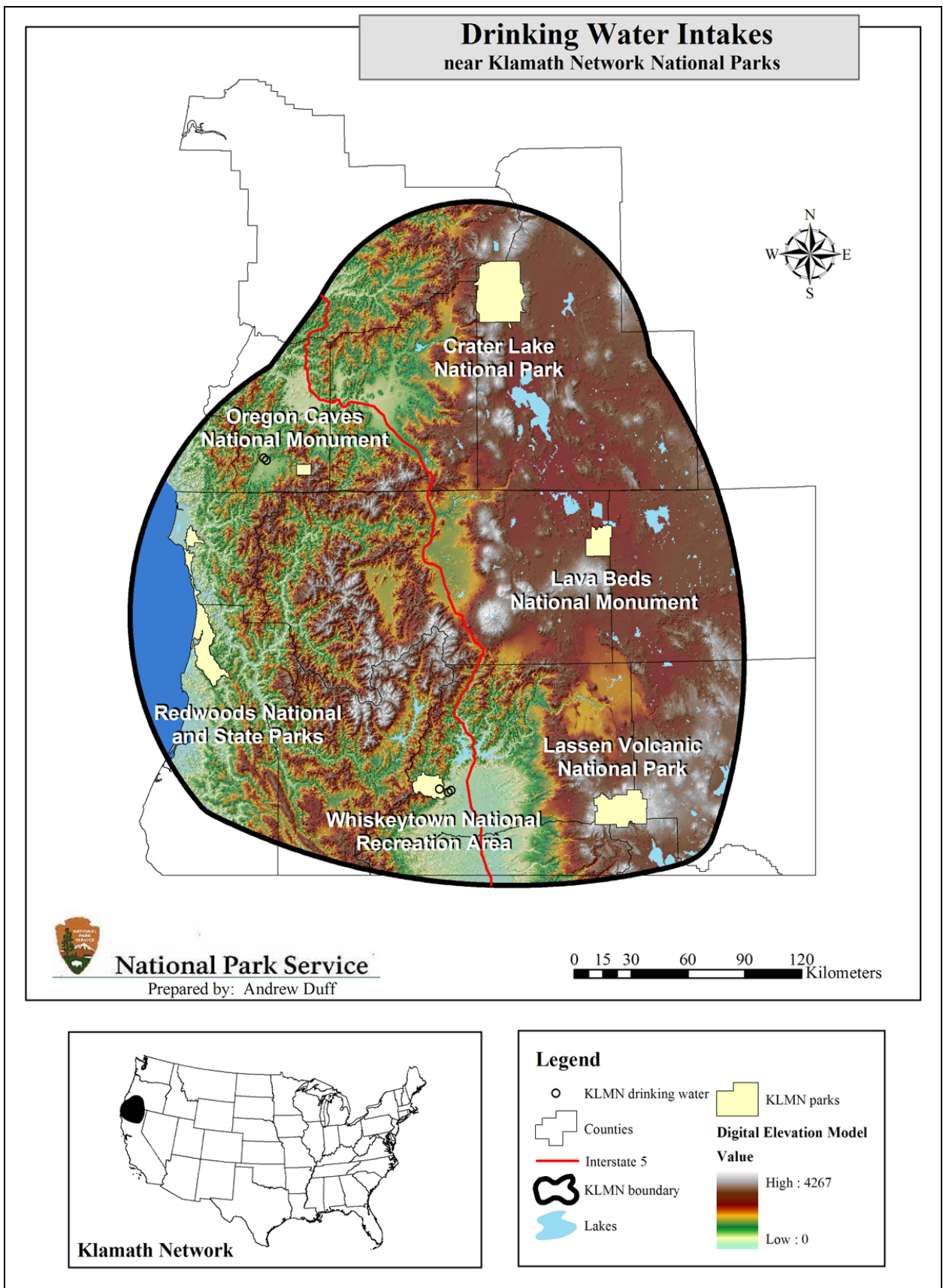
**Figure 4.** Evaporation Stations in and around the Klamath Network parks.



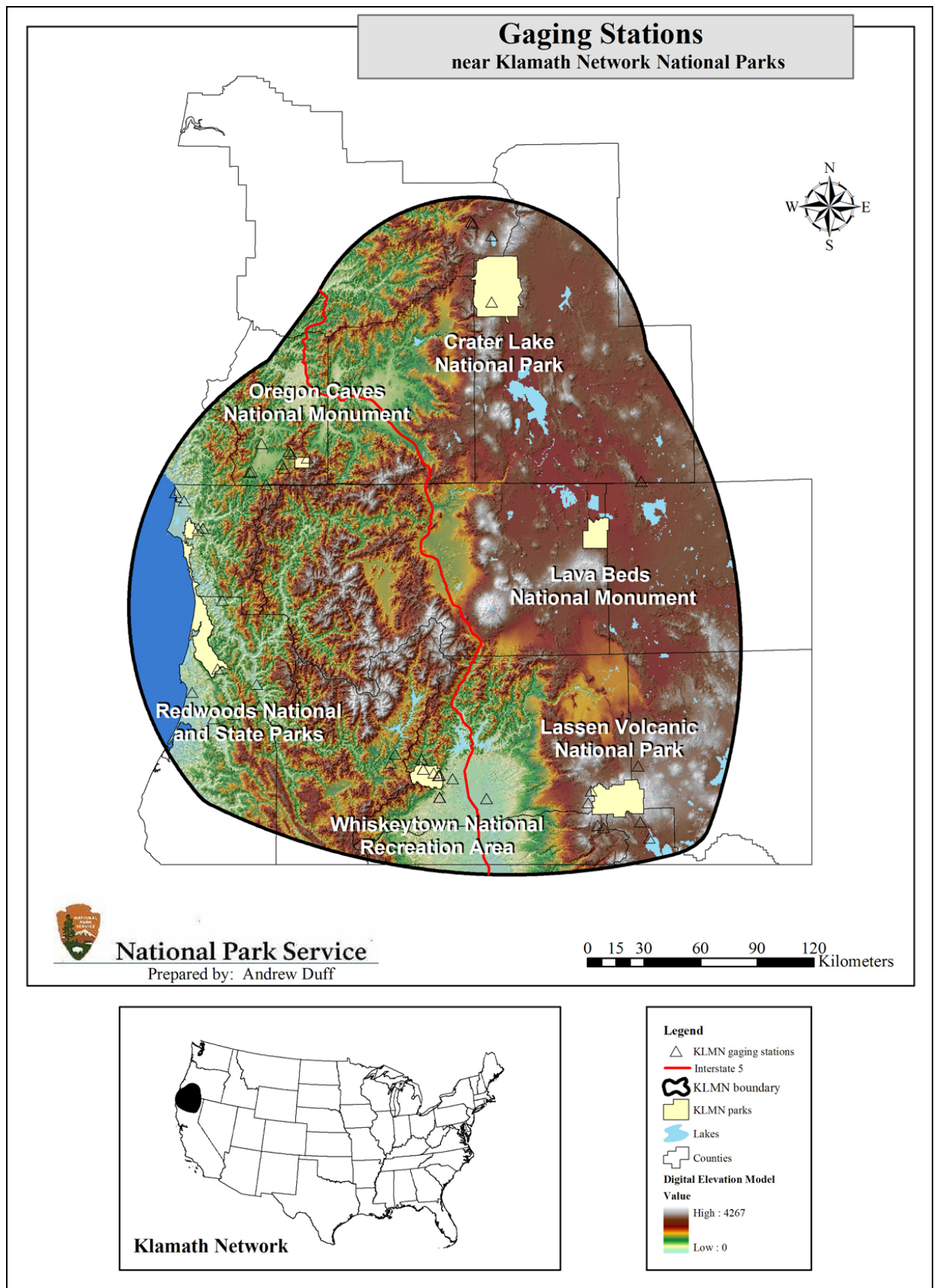
**Figure 5.** Hourly Precipitation Stations in and around the Klamath Network parks.



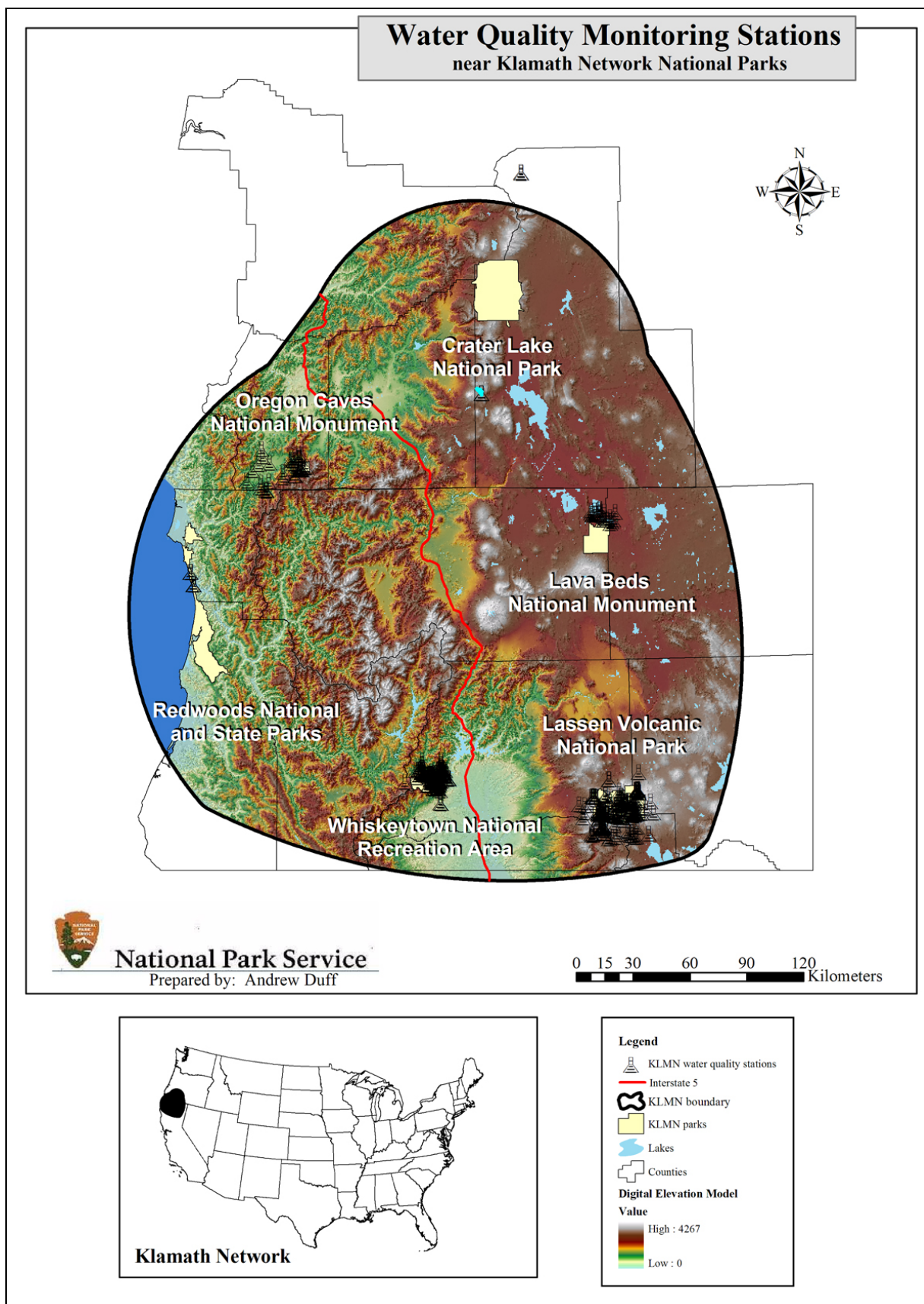
**Figure 6.** Air Temperature Stations



**Figure 7.** Drinking Water Intakes in and around the Klamath Network parks.



**Figure 8.** Gauging Stations in and around the Klamath Network parks.



**Figure 9.** Water Quality Monitoring Stations in and around the Klamath Network parks.

## **1.5. PARK-SPECIFIC RESEARCH AND MONITORING IN THE KLAMATH NETWORK PARKS**

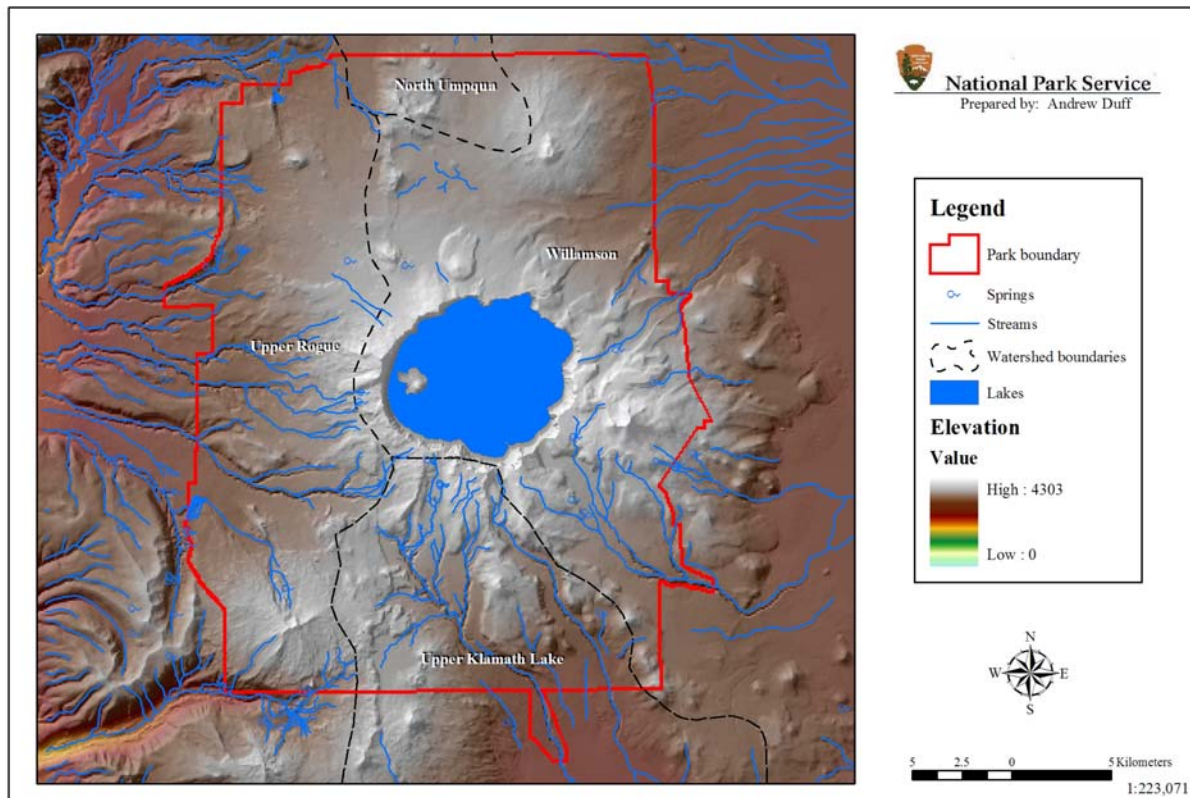
In the following section, we present a quick overview of each of the parks in the network; discuss past and ongoing water resources research, inventory, and monitoring activities; indicate whether there is a Technical Summary Report (Horizon Report -- see description below) and give some key findings from the report, if available; and list other aquatic and fisheries monitoring studies.

The Horizon Report is a Technical Report of Baseline Water Quality Information and Analysis compiled by the National Park Service's Water Resources Division. Typically, the report contains information from several sources, including: (1) Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS). The document provides:

- (1) a complete inventory of all retrieved water quality parameter data, water quality stations, and the entities responsible for the data collection
- (2) descriptive statistics and appropriate graphical plots of water quality data characterizing period of record, annual, and seasonal central tendencies and trends
- (3) a comparison of the park's water quality data to relevant EPA and WRD water quality screening criteria
- (4) an Inventory Data Evaluation and Analysis (IDEA) to determine what Servicewide Inventory and Monitoring Program "Level I" water quality parameters have been measured within the study area.

Accompanying the report are disks containing digital copies of all data used in the report, as well as all components of the report (tables, figures, etc.). Interested parties can download a report at the National Park Service's Water Resource Division web site at (<http://www.nature.nps.gov/water/horizon.htm>).

## A. Crater Lake National Park



**Figure 10.** Crater Lake National Park, showing park aquatic resources and watershed boundaries.

### *Background*

Crater Lake National Park was established as the sixth park in the NPS by Presidential Proclamation in 1902. The 73,775 hectare (182,304 acre) park is located at the southern end of the Cascade Mountains in south-central Oregon. Crater Lake was set aside as a result of the large natural caldera lake formed after the eruption of Mt. Mazama 7700 years ago. The lake that is now in existence fluctuates between 1881 and 1882 meters in surface elevation on seasonal basis, but fluctuations of up to 5 meters have been recorded in the period of record (Redmond 1990). It is the seventh deepest and the clearest lake in the world. Secchi disk readings as deep as 40 meters have been recorded for the lake. Due to its strikingly deep topaz color, Crater Lake it is one the most natural areas in the world.

In the 1980s, as a result of recent studies suggesting a decline in clarity, the U.S. congress mandated that Crater Lake National Park implement an intensive study to determine if the lake was becoming eutrophic. The lake supports populations of introduced rainbow trout and kokonee salmon. The lake inventory studied the springs feeding into the lake, physical/chemical and biological properties of the lake, and possible influence of sewage from development along the southwest rim (see studies in Drake et al. 1990). Funding

was appropriated for a deep water study of the lake's benthos, to determine if thermal activity was present, as well as studies of some of the benthic features (deep lake chemical species, sedimentation, benthic cores, aquatic vegetation and their associated communities, etc.). A Long Term Ecological Monitoring Program (LTEM) was established and is now supported with park base funding.

Crater Lake contains within its boundaries a number of aquatic resources besides the blue lake for which the park is famous. The southern area of the park contains Quillwort and Whitehorse ponds, both permanent features that sustain populations of macro/micro-invertebrates (amphibians, amphipods, ostricopds, phytoplankton, and zooplankton). Quillwort has a unique population of unidentified fairy shrimp. To the western side of the park there exist various wetland areas such as Thousand Springs, Sphagnum bog, and elk mud wallows. Many of these features have yet to be studied or comprehensively inventoried. The steep walls within the caldera contain various springs that have been inventoried and a select number are monitored as part of the lake's Long Term Ecological Monitoring Program (LTEM). Several streams originate on the outside caldera walls, particularly in the south and eastern area that are the headwaters of the Klamath River: Anne and Sun Creeks. Sun Creek is in a long-term program to re-establish native bull trout and eradicate introduced brook trout.

#### *Horizon Report Synopsis*

No Horizon report is available as yet.

#### *Aquatic Studies*

- Long Term Ecological Monitoring Program (LTEM) on the lake (on going)
  - Bathymetric lake study and map in conjunction with USGS
  - Deep lake study of bottom by OSU/NPS/Nat. Geographic
    - Movies (VHS, mpeg, etc...)
    - Data
    - Sample collection and vouchering at Crater Lake
    - Benthic core sampling
  - Fish introduction to lake, removal NO (on-going, date?)
  - Physio-Chemical studies of lake
  - Phyto/Zoo-plankton within lake pelagic zone
- Bull trout on streams (on going)
- Amphibian Research and Monitoring Institute studies (on-going)
- Whitehorse Pond inventory
- Thousand Springs study
- Spring temperature measurements around Crater Lake

#### *Fisheries Studies*

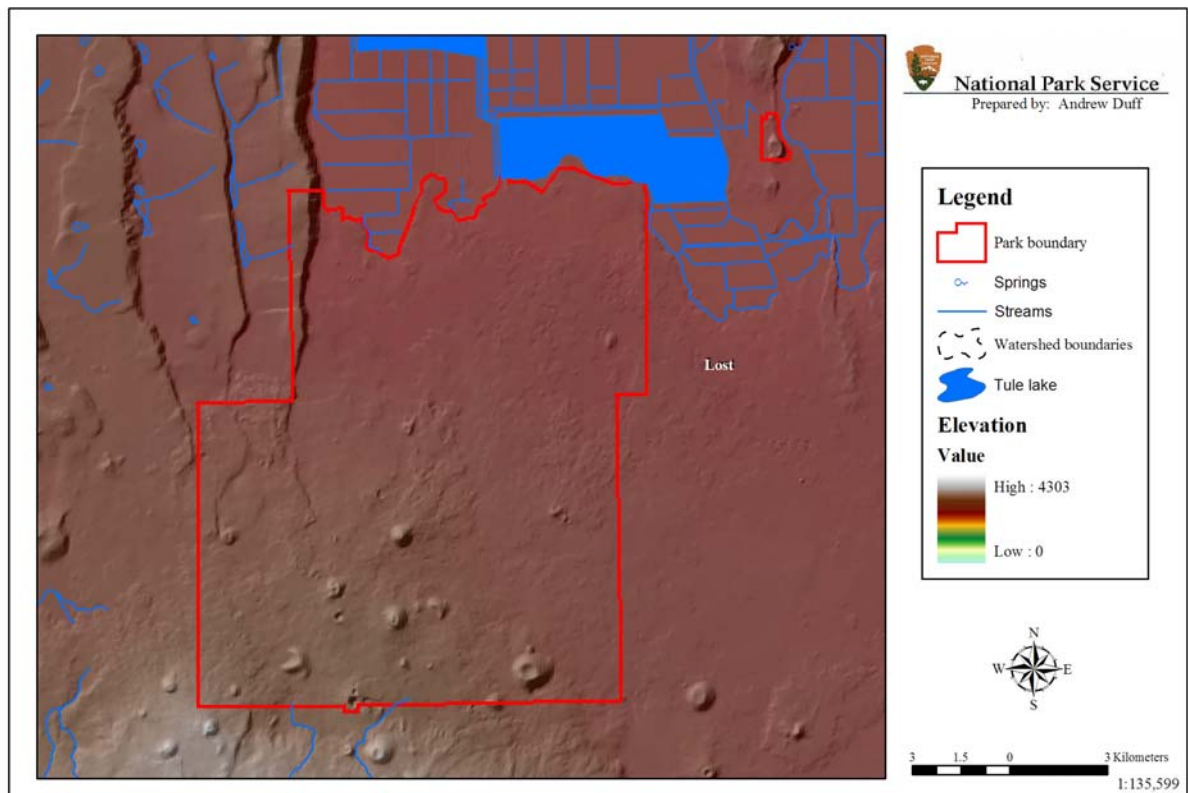
- Long term study of introduced rainbow trout (*Oncorhynchus mykiss*) and kokanee salmon (*Oncorhynchus nerka*) within Crater Lake.

- Bull trout (*Salvelinus confluentus*) restoration and brook trout (*Salvelinus fontinalis*) eradication within the Klamath River Basin (Sun Creek).
- Fish survey of all Klamath River basin tributaries within Crater Lake National Park.

### *Water Quality Concerns*

- 1) An extensive inventory of all aquatic resource locations within the park boundary and ArcGIS feature datasets has yet to be created.
- 2) Long-term clarity of Crater Lake and health of the lake ecosystem.

## **B. Lava Beds National Monument**



**Figure 11.** Lava Beds National Monument, showing aquatic resources and watershed boundaries

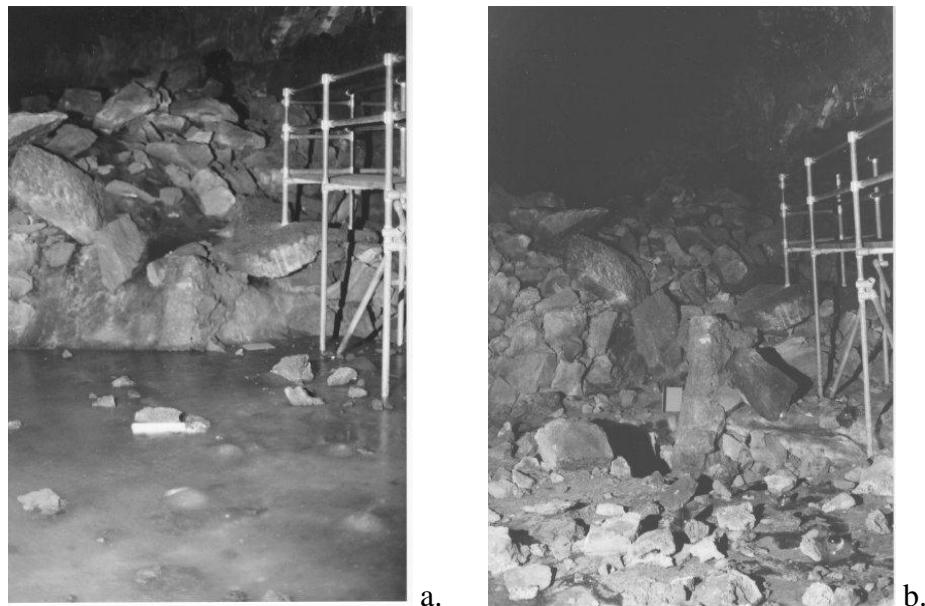
### *Background*

Lava Beds National Monument was established by Presidential Proclamation in 1925 to preserve for public enjoyment the area's dramatic volcanic geology, as represented by lava tubes, cinder cones, spatter cones, lava flows, and other volcanic phenomena. The 46,560 acre monument is located on the margin of the Cascade Range and the Great Basin Geologic Provinces in northeastern California. The Monument contains a range of

Great Basin vegetation communities, including ponderosa pine forests, mountain mahogany/juniper, and sagebrush/bunchgrass.

Lava Beds National Monument currently has 502 documented lava tube caves within the monument, with a total of 28.71 miles of passageway. No permanent or ephemeral streams or wetlands are found within the monuments boundary. A total of 28 caves within the monument are documented to contain ice and water. Many of these caves are important water sources for wildlife and historically have been used by an array of different people, including indigenous groups, ranchers and illegal moonshiners. Specific wildlife that benefit from these ice resources includes 14 species of bats and a number of different bird species. Two of the bat species that have been documented using the ice/water resources within the caves are Townsend's big eared bat (*Corynorhinus townsendii*), a species of concern, and Mexican free-tail bat (*Tadarida brasiliensis*), the largest northern migratory colony of this species in the United States. Over the last ten years, the Mexican free-tail bat population that seasonally visits the monument has been documented to contain over 200,000 bats.

In 1999, a Student Conservation Associate conducted a water sampling project on 14 ice caves within the Monument. This was the first sampling of water resources in the Monument's caves. Between 1990 and the present, eight ice cave floors are monitored by Cave Research Foundation for changes in ice depths. In 1999, Merrill Ice Cave, one of the larger ice resources in the monument, began to erode with the formation of a hole in the center of the ice floor. By 2001, the entire ice resource had practically disappeared. It is paramount that a water quality baseline be established before possible future losses occur in other caves.



**Figure 12.** Merrill ice floor in (a)1990 and (b) 1999.

### *Horizon Report Synopsis*

A Horizon Report is available for the Lava Beds National Monument at:  
([http://nrddata.nps.gov/LABE/nrddata/water/baseline\\_wq/docs/LABEWQAA.pdf](http://nrddata.nps.gov/LABE/nrddata/water/baseline_wq/docs/LABEWQAA.pdf)).  
Please see horizon report for a look at the research it summarizes

### *Aquatic Studies*

Note: There are no real surface waters within the park boundary other than the ice cave sources, and that therefore there were no survey stations within the park, only in adjacent Tule Lake National Wildlife Refuge (NWR).

- 1) Ice cave studies.
- 2) Groundwater study.
- 3) Water quality inventory within ice caves (Klamath Network-FY04, Chris Currens, USGS WERC). Beginning in 2004, water sampling at Lava Beds will occur in 12 of the known total 28 ice caves. Sampling will occur in caves identified as primary ice resources for the monument. The selection of caves will also be based on ease of access, technician safety, and cave resource sensitivity.
- 4) Ice levels in six ice caves have been monitored since 1990 by Cave Research Foundation.
- 5) Ice cave geomorphology.
- 6) search effects of geothermal developments.
- 7) Assess effects of adjacent land uses on park resources (agricultural use, insecticides/pesticides; accumulation within Tule Lake; Tule Lake NWR management/land use).

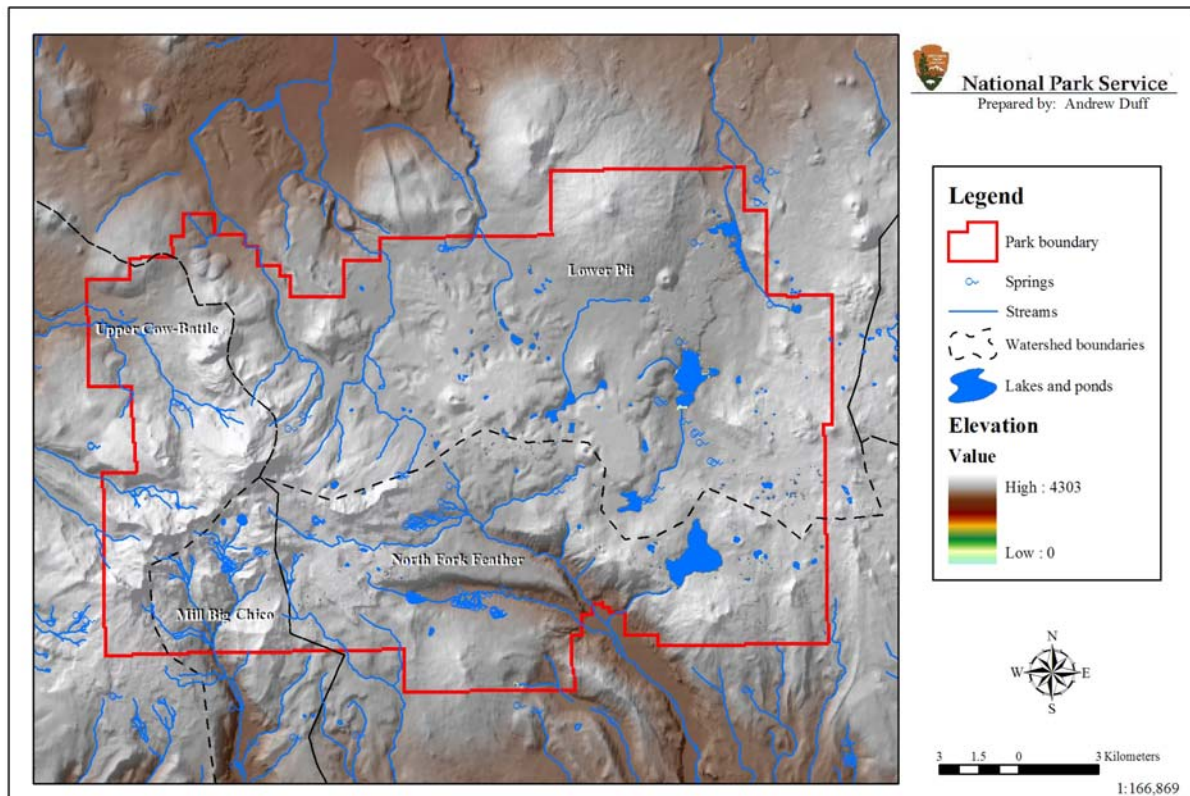
### *Fisheries Studies*

Fisheries studies are not applicable since there is no surface water within the Park's boundaries.

### *Water Quality Concerns*

- 1) Loss of ice within caves.

## C. Lassen Volcanic National Park



**Figure 13.** Lassen Volcanic National Park, showing park aquatic resources and watershed boundaries.

### *Background*

Lassen Volcanic National Park is a 106,372-acre NPS unit located in the southern range of the Cascades in northeastern California. The landscape is dominated by volcanic processes and includes 277 permanent and ephemeral lakes. Portions of five drainage basins are located within the park boundaries, and four of the drainage basins (nearly the entire park, about 99%) drain into the Sacramento River and eventually to the Pacific Ocean. All of the Park's lakes and streams are considered important for wildlife and several receive high visitor recreational use. Several Park lakes were formerly stocked with trout for recreational fishing and now contain self-propagating populations. Mill Creek currently has no dams blocking anadromous fish and is one of a very few stream courses remaining in California with biologic integrity preserved from its origin in northern California to the Sacramento River.

There are several vertebrate and invertebrate taxa associated with aquatic environments within Lassen Volcanic that are on Federal and/or State lists as protected species. Kings Creek Parapsyche Caddisfly (*Parapsyche extensa*) is a federal species of concern, the Modoc Sucker (*Catostomus microps*) is listed as endangered on both lists, and the Cascades Frog (*Rana cascadae*) is listed as a federal and state species of concern.

### *Horizon Report Synopsis*

A Horizon Report is available for the Lassen Volcanic National Park at:  
([http://nrddata.nps.gov/LAVO/nrddata/water/baseline\\_wq/docs/LAVOWQAA.pdf](http://nrddata.nps.gov/LAVO/nrddata/water/baseline_wq/docs/LAVOWQAA.pdf)).

Here is a list of the research summaries available in that report:

- 1) San Jose State inventory
- 2) Water quality inventory (Klamath Network-FY04)
- 3) “A Survey of General Ecological Condition in a Group of Lakes in Lassen National Park 1969” by Paul M. Hubbell of Humboldt State University.
- 4) “Lassen Park Summer 1979 Lake Surveys”
- 5) “A Survey of Horseshoe and Snag Lakes and Their Tributaries; Lassen Volcanic National Park; June – September 1963” by Fred H. Everest (part I of a Humboldt State University Project).
- 6) “Chemical Analyses of Thermal and Nonthermal Springs in Lassen Volcanic National Park and Vicinity” by J. Michael Thompson 1983.
- 7) “The Lassen Geothermal System” by Muffler, Nehring, Truesdell, Janik, Clynne, and Thompson 1976.
- 8) USGS WRD summary of a brief field survey of Lassen Volcanic National Park by E.J. McClelland (Sacramento) August, 1973.
- 9) USGS by Robin Lenn 1964 (these are from data sheets only).
- 10) USGS WRD misc. samplings: 1973, 1986-88, 1989, 1993, 1994
- 11) USGS 1979-81.
- 12) NPS sampling 1989 from Lassen Volcanic.
- 13) Unknown report, 1993.
- 14) “Report on Field Trip to Lassen Region on August 1-5; 1983” USGS by Michael L. Sorey 1983.
- 15) NPS spreadsheet (RL\_1986.xls) from Lassen Volcanic.
- 16) Miscellaneous NPS sampling from Lassen Volcanic 1986-92.
- 17) “A Survey of Manzanita and Reflection Lakes: Lassen Volcanic National Park: June – September 1961 by Paul M Hubbell of Humboldt State University.

### *Aquatic Studies*

- Bufflehead duck long term monitoring was begun in 1997.
- Dr. John DeMartini (Humboldt State University) has conducted snorkeling surveys of lakes.

### *Fisheries Studies*

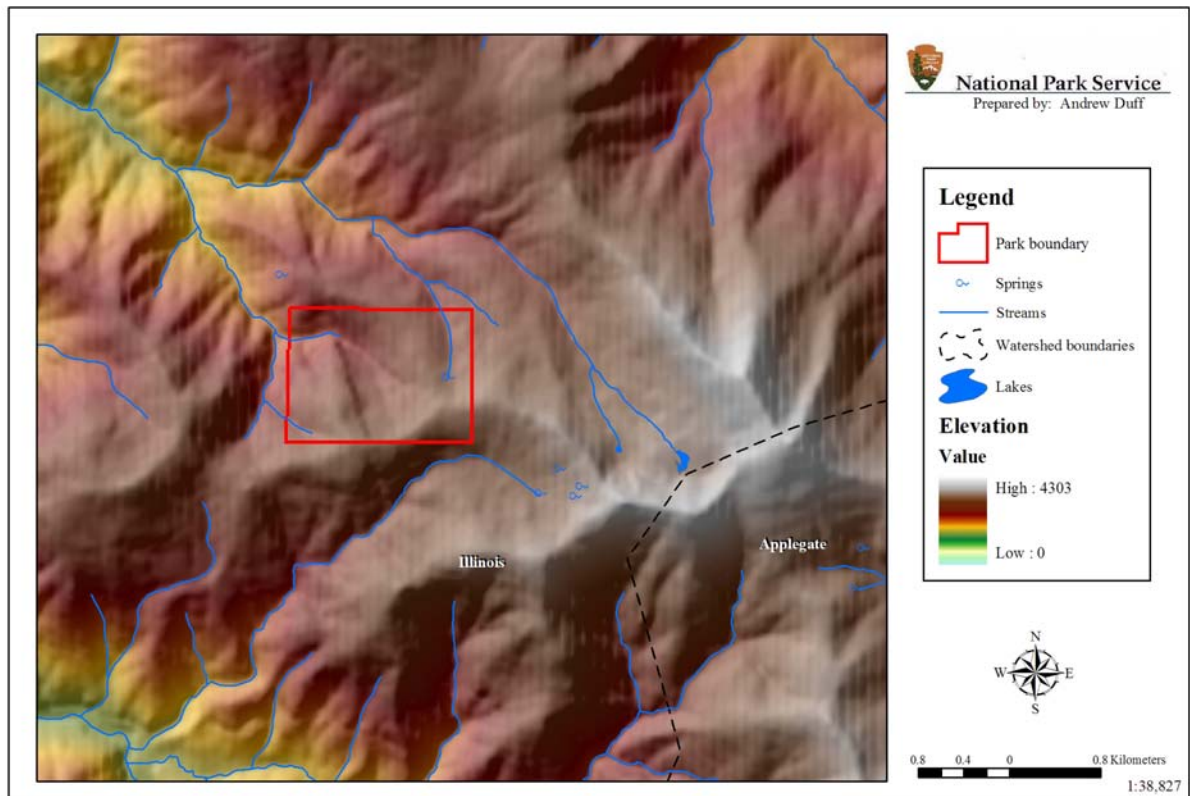
Status of the trophy rainbow trout fishery at Manzanita Lake (Lassen Volcanic National Park) based on reports from angler survey boxes in 1994.  
Surveys of the Sifford Lakes, Lassen Volcanic National Park, 2000

Summary of 1976 lake survey data relating to the status of trout fisheries in Lassen Volcanic National Park  
Status of the Manzanita Lake trout fishery, Lassen Volcanic National Park, 1998.  
Management of fishing and fish stocking in National Parks in California, 1975.  
Aquatic resources of Lassen volcanic, Sequoia-Kings Canyon, and Yosemite National Parks, with special reference to trout stocking and the recreational fishery, 1978.  
Snag Lake Management Report, 1976.  
Management of high country lakes in the National Parks of California, 1976.  
An analysis: Impacts of trout stocking upon recreational fishing and aquatic resources in Lassen Volcanic, Sequoia and Kings Canyon, and Yosemite National Parks, California, 1977.  
Food Habits Analysis of Fish from Mountain Lakes in Lassen Volcanic National Park, California. 1977.  
FY04 Joint inventory of fishes, native amphibians, and invertebrates in all lakes and ponds of the park.

#### *Water Quality Concerns*

- 1) An extensive inventory of all aquatic resource locations within the park boundary and ArcGIS feature datasets have yet to be created
- 2) Deterioration of geothermal areas as a result of visitor impacts.

## D. Oregon Caves National Monument



**Figure 14.** Oregon Caves National Monument, showing aquatic resources and watershed boundaries.

### *Background*

Oregon Caves National Monument is a 480-acre National Park unit located in the Siskiyou/Klamath bioregion of southern Oregon. Although the Monument is a small park unit, forest communities contained in the Monument are a diverse representation of the larger bioregion, with old growth Douglas Fir, white fir, and oak forests covering the majority of the monument and providing diverse microhabitat opportunities for the monument's nearly 500 plants, 5,000 animal, and 2,000 fungal species – which are among the highest catalogued per acre for any national park unit. Federally threatened and endangered species of concern found in the monument include the Del Norte salamander and Western toads. All of the Monument's cave pools, springs and streams are considered important water resources for wildlife.

### *Horizon Report*

A Horizon Report for the Oregon Caves National Monument is available at:  
([http://nrddata.nps.gov/ORCA/nrddata/water/baseline\\_wq/docs/ORCAWQAA.pdf](http://nrddata.nps.gov/ORCA/nrddata/water/baseline_wq/docs/ORCAWQAA.pdf))

The list below is from the report:

- 1) NPS Oregon Caves sample collection, 1992-93 (Baseline water quality inventory of waters in: near: and contributing to the cave system)
- 2) Data at Oregon Caves 0020 is from some unreported data from 1966, see if I can find the info (it is data for a station within the cave)

#### *Aquatic Studies*

- 1) Creek water within-cave study (ongoing by John Salinas, Rogue Valley Community College)
- 2) Water quality inventory (Klamath Network-FY04, Chris Currens, USGS WERC)

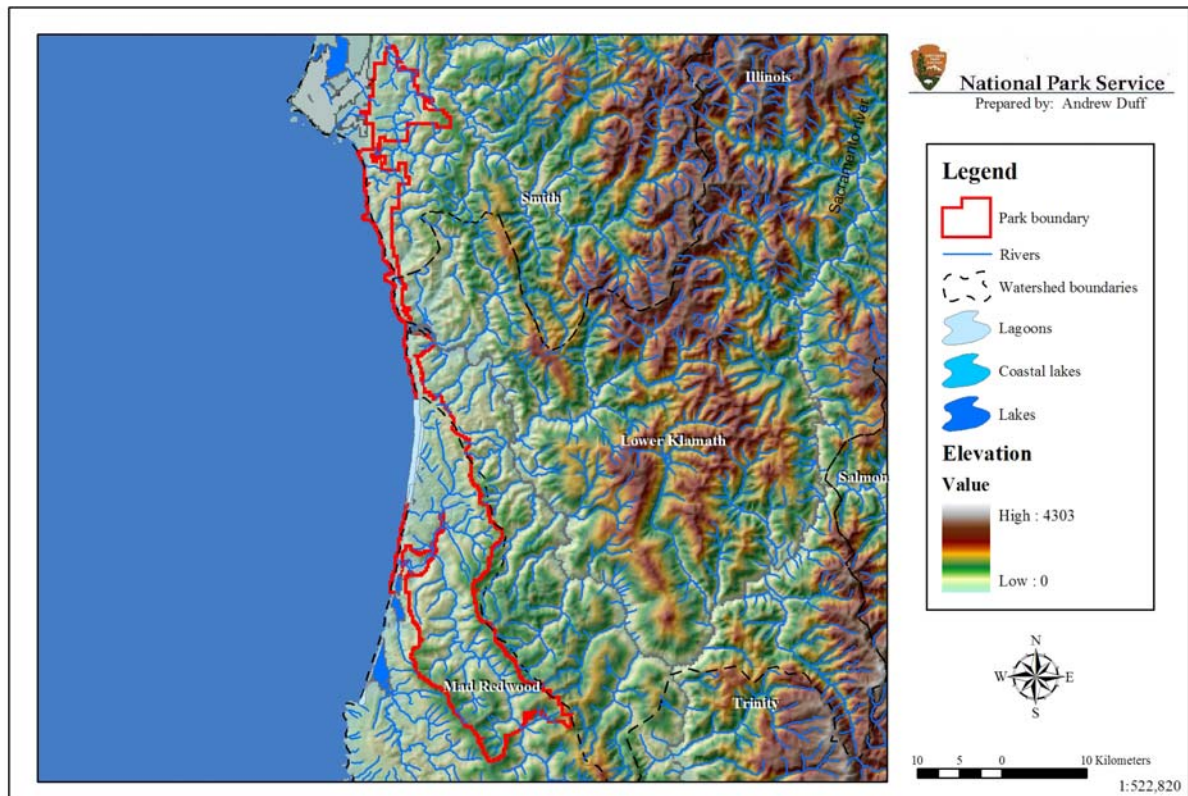
#### Fisheries Studies

None known. The anadromous salmonid species historically found within the park unit boundaries have been extirpated.

#### *Water Quality Concerns*

- 1) Water quality (heavy metals, human-caused organic enrichment, calcite solubility index, turbidity), volume, and timing of cave infiltration, cave stream, spring, and surface stream water (likely drainfield and possible pavement hydrocarbon contaminates)

## E. Redwood National and State Parks



**Figure 15.** Redwood National and State Parks, showing aquatic resources and watershed boundaries.

### *Background*

Redwood National and State Parks were established in 1968 by Presidential Proclamation. The parks are 42,700 ha (105,516 acres) in size, arrayed along the Pacific Coast of northern California. On its western side, the national park boundary extends 0.25 miles (1,320 feet) beyond the Pacific Ocean's mean high tide line, and the National Park Service exercises jurisdiction over the waters, intertidal lands, and submerged lands. The coastal jurisdiction of state parklands extends 1,000 feet west of the ordinary high-water mark. Elevations within the park range from sea level to 996 meters (3,267 feet) at an unnamed peak in the Coyote Creek drainage.

The aquatic resources of Redwood National and State Parks consist of over 60 km (37 mi) of marine coastal habitat (extending 0.42 km (0.25 mi) off shore) and various lotic environments. Redwood Creek and its associated watershed dominates the southern part of the park. The Klamath River is in the north area of the park and the river's estuary is the only part of the drainage contained within park boundary. Redwood supports a number of salmonid species; cutthroat trout (*Oncorhynchus clarki*), coho salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss*), chinook salmon (*Oncorhynchus tshawytscha*) that are monitored on an annual bases. Green sturgeon (*Acipenser medirostris*), Klamath smallscale sucker (*Catostomus rimiculus*), and the

tidewater coby (*Eucyclogobius newberryi*) are threatened and endangered species that are monitored on an annual basis within the park. The park also supports a number of additional threatened and endangered species (see Appendix E).

Perhaps the chief concerns regarding water quality are the impacts of logging and logging roads on private lands within the Redwood Creek watershed. This drainage has been a site of intensive restoration and geomorphic research for many years and efforts at restoration continue. The coastal resources are largely unexplored, and their condition is presently unknown.

### *Horizon Report Synopsis*



No report is available yet.

### *Aquatic Studies*

1. Salmonid monitoring is done, both for adults returning for spawning and for juveniles within the estuary, only within Redwood Creek. Redwood Creek is also monitored for deformed amphibians.
2. Monitoring of marine mammal carcasses is ongoing.
3. Marbled murrelet, snowy plover and brown pelican are monitored.

### Fisheries Studies

Smolt production from Prairie Creek Hatchery juvenile coho reared in an Arcata wastewater-seawater pond, October 1992-May 1993.

Coyote Spring Pond Brook Trout, 1999.

Invertebrate drift and juvenile salmonid habitat of Redwood Creek watershed, 1981.

1988 fish trapping in the South Slough of the Redwood Creek estuary.

Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California, 1988.

1991 Redwood Creek summer steelhead trout survey.

Redwood Creek estuary monitoring and management: 1990.

1992 Redwood Creek summer steelhead trout survey.

1993 Redwood Creek estuary annual monitoring.

Summary of reports relating to coho salmon (*Oncorhynchus kisutch*) in the Redwood Creek basin, 1994.

1997 Redwood Creek estuary annual monitoring.

Redwood Creek basin 1996-1997 spawning and carcass survey.

1997 annual tidewater goby activities.

1998 Redwood Creek summer steelhead trout survey.

1998 Redwood Creek estuary monitoring.

1998 tidewater goby survey.

1999 Redwood Creek summer steelhead trout survey.

Coyote Creek spring pond brook trout removal, 1999.

Redwood Creek basin 1997-1998 spawning and carcass survey.

1999 Redwood Creek estuary annual monitoring report.

Coyote Creek Spring Pond brook trout removal, 2001.

2002 Redwood Creek summer steelhead trout survey.  
 2002 tidewater goby annual report.  
 Coyote Creek Spring Pond brook trout removal, 2002.  
 Redwood Creek estuary monitoring 2002.  
 Anderson, D. G. 2004. 2003 snorkel monitoring activities Redwood National and State  
 Parks- Fish and Wildlife Branch..  
 Redwood Creek estuary monitoring 2003.  
 Redwood Creek basin 1991-1992 spawning and carcass survey.  
 Fish habitat inventory for lower Lost Man Creek, 1990.  
 Survival, growth and movement of juvenile coho salmon (*Oncorhynchus kisutch*) over-  
 wintering in alcoves, backwaters, and main channel pools in Prairie Creek,  
 California, 2001.  
 Abundance and survival rates of juvenile coho salmon (*Oncorhynchus kisutch*) in Prairie  
 Creek, Redwood National Park, 2002.  
 Assessment of fish habitat types within the Klamath River estuary: annual performance  
 report, 1992.  
 Effects of sedimentation on incubating coho salmon, (*Oncorhynchus kisutch*) in Prairie  
 Creek, California, 1998.  
 Interim report: Coho salmon survival in northern California streams of varying habitat  
 quality, 1999.  
 Prairie Creek salmon restoration, 1992-1993 season.  
 Monitoring of aquatic impacts associated with construction of the Redwood Park Bypass,  
 US Highway 101.  
 Redwood Creek basin 1993-1994 spawning and carcass survey: Annual progress report.  
 Use of radio telemetry to study upriver migration of adult Klamath River chinook  
 salmon, 1982.  
 1997 Smith River Adult Fish.  
 Fish distribution survey report, FY 2000.  
 Fish distribution survey report, FY 2001.  
 Fish distribution survey report, FY 2002.  
 Redwood Creek basin 2002-2003 spawning and carcass survey, annual progress report.  
 Large organic debris and anadromous fish habitat in the coastal redwood environment:  
 the hydrologic system, 1983.  
 Salmon redd composition, escapement and migration studies in Prairie Creek, Humboldt  
 County, California, 1996-1997.  
 Utilization of the Klamath River estuary by juvenile chinook salmon (*Oncorhynchus*  
*tshawytscha*), 1986.  
 Habitat utilization by the 1987 and 1988 cohorts of chinook salmon from emergence to  
 outmigration in Hurdygurdy Creek, California.  
 Downstream migration, growth and condition of juvenile fall chinook salmon in  
 Redwood Creek, Humboldt County, California, 1985.  
 Effects of large organic debris on channel morphology and process, and anadromous fish  
 habitat in steep mountain, coast redwood environments, 1980.  
 Redwood Creek basin fisheries summary, 1980-1994.  
 Effects of fine sediment on salmonid redds in Prairie Creek, a tributary of Redwood  
 Creek, Humboldt County, California, 1991.

Redwood Creek salmon spawner survey 2000/01 season.  
 Redwood Creek fish and amphibian distribution data [collection].  
 Spawning survey results, 1983 - 1990.  
 Aquatic ecosystem analysis of two logged and two unlogged watersheds in Redwood National Park and Prairie Creek Redwood State Park, 1976.  
 Mill Creek monitoring program: juvenile salmonid monitoring on the east and west branches of Mill Creek, 1994.  
 Redwood Creek estuary flood history, sedimentation and implications for aquatic habitat, 1983.  
 Fishery resources of the Redwood Creek basin, 1994.  
 Anadromous salmonid escapement and downstream migration studies in Prairie Creek, California, 1995-1996.  
 Effects of sediments from the Redwood National Park bypass project (CALTRANS) on anadromous salmonids in Prairie Creek State Park 1995-1998.  
 Assessing the effects of moderately elevated fine sediment levels on stream fish assemblages, 2000.  
 Fish food habits and their interrelationships in lower Redwood Creek, Humboldt County, California, 1987.  
 Food habits of fishes in the Redwood Creek estuary, 1990.  
 Hoopa Valley Indian Reservation inventory of reservation waters, fish rearing feasibility study and a review of the history and status of anadromous fishery resources of the Klamath River Basin, 1979.

### *Beneficial Water Uses*

Table 2 shows the beneficial uses of water in the Redwood National and State Parks, as identified by the North Coast Regional Water Quality Control Board (NCRWQCB).

Table 2. Beneficial uses within Redwood National and State Parks (NCRWQCB).

<b>Acronym</b>	<b>Definition</b>
AGR	Agricultural Supply
COLD	Cold Freshwater Habitat
COMM	Commercial and Sport fishing
EST	Estuarine Habitat
FRSH	Freshwater Replenishment
GWR	Groundwater recharge
IND	Industrial Service Supply
MAR	Marine Habitat
MIGR	Fish Migration
MUN	Municipal Supply
NAV	Navigation
PROC	Industrial Process Supply
RARE	Preservation of Rare and Endangered Species
REC 1	Contact Water Recreation
REC2	Non-contact Water Recreation

SHELL	Shellfish Harvesting
SPWN	Fish Spawning
WARM	Warm freshwater habitat
WILD	Wildlife Habitat

### *Water Quality Concerns*

#### Freshwater

- 1) Effects of adjacent land use, in particular, logging
- 2) Clean Water Act (CWA) Section 303d impaired stream segments
  - a. 303d at Redwood Creek, temperature (ongoing)
  - b. 303d at Klamath River, sediment (ongoing)
- 3) Marine intertidal inventory (FY04)
- 4) Redwood Creek watershed study (on going)
- 5) Geohydrological reconnaissance and study (1969)
- 6) Redwood Creek, sediment transport trends (1970s)
- 7) Redwood Creek, water and suspended-sediment discharge (1973-1975)
- 8) Redwood Creek, water chemistry and aquatic biology (1973-1975)

A full discussion of the CWA Section 303d listing and Total Maximum Daily Load (TMDL) program process can be found at the following EPA web site:

<http://www.epa.gov/owow/tmdl/>

#### Marine

1. Is the water quality of the marine component of near- and off-shore waters within acceptable State Water Quality Control Board Standards?
2. What is the role of river flow output (e.g., Klamath River plume) on coastal habitat, productivity, and water chemistry.
3. Are there any contaminants in the near- and off-shore waters of Redwood National Park? Where do they occur?

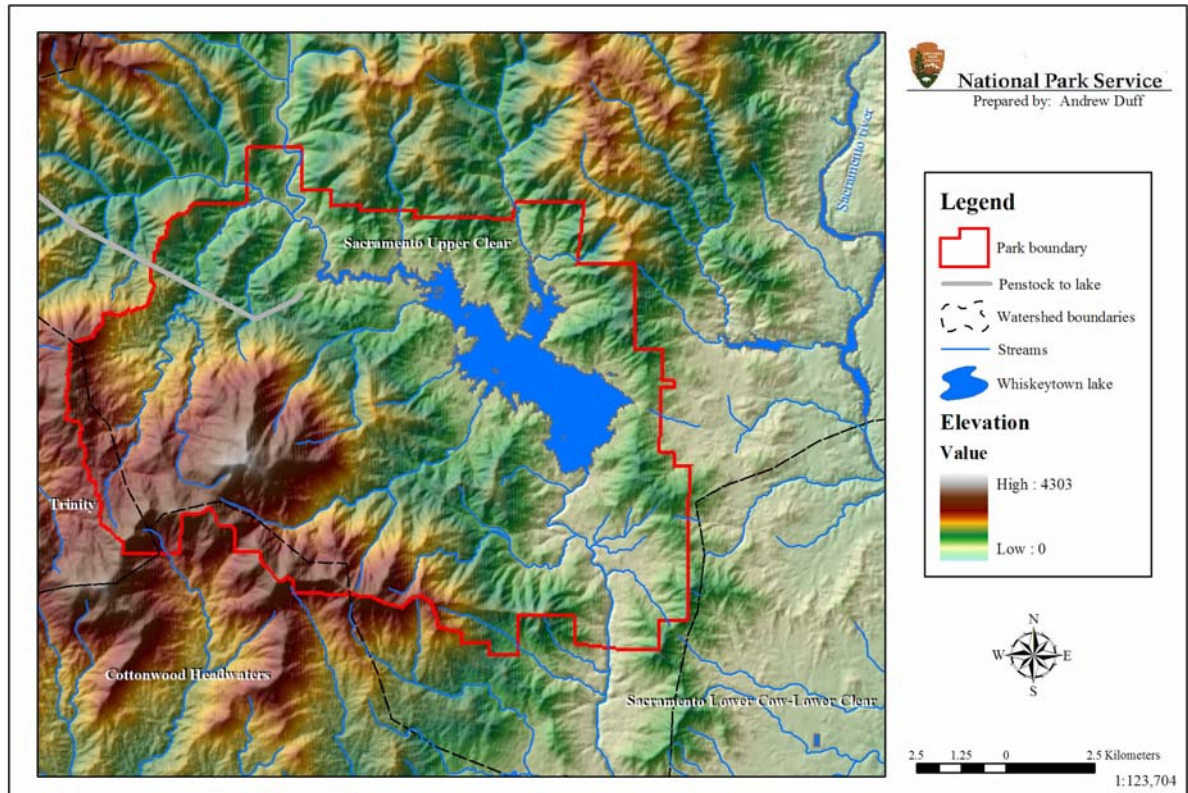
#### Inventory Needs

Table 3 shows the current marine inventory needs for Redwood National and State Parks.

Table 3. Marine inventory needs at Redwood National and State Park.

SUBTIDAL	INTERTIDAL	ESTUARY
<b>Habitat Typing</b> (Rock, Sand, Kelp) 36 miles of coastline <b>Bathymetry</b> <b>Near Shore Currents &amp; Wave Action</b> <b>Fish Distribution</b> <b>Aircraft Overflights</b>	<b>Habitat Typing</b> (Rock, Sand ) 36 miles of coastline <b>Invertebrates, Plants, Fish</b> (Distribution and Amount) <b>Large Woody Debris</b> <b>Visitor Use</b> (Areas used)	<b>Substrate Typing</b> (Rock, Sand, Mud) <b>Aquatic Plants</b> <b>Bathymetry</b>

## F. Whiskeytown National Recreation Area



**Figure 16.** Whiskeytown National Recreation Area, showing park aquatic resources and watershed boundaries.

### *Background*

Whiskeytown National Recreation Area was established by Congress on November 8, 1965 “...to provide..., for the public outdoor recreation use and enjoyment of Whiskeytown reservoir and surrounding lands...” Whiskeytown National Recreation Area is the only unit of the Whiskeytown-Shasta-Trinity National Recreation Area administered by the NPS—the Shasta and Trinity units are administered by the US Forest Service. The Whiskeytown unit is located at the northern end of the Sacramento Valley, 8 miles west of the city of Redding, California, and contains approximately 42,497 acres of shrubland, oak woodland, and montane forest which surround Whiskeytown Lake.

Whiskeytown Lake was created by the Bureau of Reclamation (BOR) in 1962, when it built the Clair A. Hill Whiskeytown Dam, blocking Clear Creek. The lake contains 3,220 surface acres (240,000-acre feet) of water at full capacity, and serves as the domestic water supply for the cities of Redding, Old Shasta, Centerville, Keswick, and Happy Valley. It is also one of several lakes that store water for the Central Valley Project. Seven major streams empty directly into the lake: Clear Creek, Mill Creek, Brandy

Creek, Crystal Creek, Boulder Creek, Willow Creek, and Whiskey Creek. Intermittent streams abound throughout the park, and many springs are found at higher elevations.

Approximately 850,000 visitors recreate at Whiskeytown annually, with the majority of the visitation concentrated in and around the reservoir. Sailing, skiing, fishing, swimming, and kayaking are popular visitor uses of the reservoir. There are two permanent marinas, one additional boat launch site, three designated campgrounds, two developed day use beaches, and numerous smaller beaches along the reservoir. The reservoir is stocked annually with both native and non-native fishes by the California Department of Fish and Game.

### *Horizon Report*

A Horizon Report for the Lava Beds National Monument is available at:  
([http://nrdata.nps.gov/WHIS/nrdata/water/baseline\\_wq/docs/WHISWQAA.pdf](http://nrdata.nps.gov/WHIS/nrdata/water/baseline_wq/docs/WHISWQAA.pdf)) .

Here is a list of the studies available in the report:

- 1) "Salt Creek; at Buck Hollow" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 2) "Clear Creek below N.E.E.D. Camp" California Dept. of Water Resources DB from a study of Clear Creek Basin from 1997-98.
- 3) Bureau of Reclamation data for Clear Creek concerning the reservoir, 1996-98.
- 4) "Clear Creek N.E.E.D. Camp Bridge" NPS Whiskeytown collected data from 1973-80.
- 5) "Orofino Gulch; at Confluence of Road" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 6) "Paige Boulder Creek; Below last Confluence east of Peltier Confluence" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 7) "Paige Boulder Creek" NPS Whiskeytown collected data from 1973-80.
- 8) "Paige Boulder Creek; at Peltier Confluence" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 9) "Clear Creek above Paige Bar" California Dept. of Water Resources DB from a study of Clear Creek Basin from 1997-???
- 10) "Clear Creek Peltier Bridge" NPS Whiskeytown collected data from 1973-80.
- 11) "Brandy Creek; at Road Junction above "Rockslides"" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 12) "West of Dam" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991
- 13) "West Side of Dam" believed by California WQCB, NPS file memo.
- 14) "Brandy Creek; at Sheep Camp Bridge" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 15) "Mid-Dam" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 16) "Whiskeytown Reservoir" California Dept. of Water Resources DB 1971-94.
- 17) "Whiskeytown Lake Intake-Raw" California Dept. of Health Services data 1986-94.

- 18) "A Water Quality Study of Whiskeytown; Black Butte; Stony Gorge and East Park Reservoirs" a report by Alexander Petrovich Jr. for California Dept of Fish and Game (Water Projects Branch) 1996.
- 19) "Whiskeytown Reservoir near the Dam" California Dept. of Water Resources DB from a study of Clear Creek Basin from 1997-98.
- 20) "East side of Dam" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 21) "East Beach; South Side" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 22) "East Beach; North Side" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 23) "Brandy Creek; at Main Powerline Overcrossing" miscellaneous NPS Whiskeytown data found in a brown folder called "Water Quality" 1984.
- 24) "Below Park Headquarters" 4 bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 25) "South of Park Headquarters" believed by California WQCB, NPS file memo 1976-77.
- 26) "Headquarters (Whiskeytown Lake)" California Dept. of Health Services data 1984-91.
- 27) "Background in Eastern portion of Lake," bacterial surveys by California WQCB 1986, 1987, 1990, 1991.
- 28) "Brandy Creek" NPS Whiskeytown collected data from 1973-80.
- 29) "Brandy Creek; NW ¼ SW ¼; SECT. 20; T32N; R6W" from a report by USGS titled "Water-Resources reconnaissance of Whiskeytown National Recreation Area; California" from 1969.
- 30) "Unnamed Gulch; NE ¼; SE ¼; SECT. 20; T32N; R6W" from a report by USGS titled "Water-Resources reconnaissance of Whiskeytown National Recreation Area; California" from 1969.

### *Fisheries Studies*

- USFW and NMFS have been conducting a number of studies on the anadromous fish within the lower Clear Creek.
- Studies are underway on the genetics of Clear Creek Chinook salmon as a result of habitat improvement projects.

### *Water Quality and other Concerns*

- 1) Extensive inventory of all aquatic resource locations within the park boundary and ArcGIS feature datasets created
- 2) Disturbance of aquatic stream habitats by illegal Marijuana growers
- 3) Exotic plant species within Whiskeytown Lake
- 4) Non-native fish and wildlife species (particularly bullfrogs)
- 5)

## **1.6. COMMON INVENTORY, MONITORING, AND RESEARCH THEMES ACROSS PARKS**

From these basic descriptions of park inventory, monitoring, and research activities, several common themes emerge. Parks are quite interested in establishing the *baseline water quality* of freshwaters and in *salmonid fisheries*, where applicable. *Amphibian* surveys have also been implemented in all the parks and there is currently interest in incorporating the parks in long-term monitoring efforts by allied agencies such as the USGS Amphibian Research and Monitoring Initiative (ARMI) program.

Several inventory, monitoring, or research needs have been identified, including a need for more consistent freshwater inventory and monitoring techniques across parks, and a general monitoring program for the marine environment at Redwood. Wetland plant and animal inventories have also been identified as an information need, and the network also needs a high quality digital map for all existing water bodies in the program.

## **1.7. NETWORK-WIDE SCOPING AND ISSUES IDENTIFICATION FOR VITAL SIGNS MONITORING**

### **A. Purpose, Need, and Approach**

The Klamath Network is in the process of developing a long-term water quality monitoring plan for its parks. Development of the water quality monitoring plan has followed the guidance given in a May 2002 Memorandum to NPS Regional I&M Coordinators. The memo outlines a three-phase approach for developing a monitoring plan beginning with Phase I -- an introduction and background on the parks. Phase II provides more depth and discusses the specific “vital signs indicators” (indicators of ecosystem health) to be monitored. Water quality issues were an important element of the Klamath Network’s Vital Signs Scoping Process.

In addition to its general vital signs scoping process, the Klamath Network identified the need for a working water quality subgroup of the Science Advisory Committee (SAC). The subgroup was given the task of making recommendations concerning water quality issues and implementing those tasks that the SAC considered significant. Their first assignment was to recommend additional Phase I basic water quality inventories for three of our parks (Lava Beds, Lassen Volcanic, and Oregon Caves) based upon the advice of the NPS-WRD’s preliminary evaluation of existing water quality information and its currency.

The other task required of the water quality subgroup for this fiscal year was the development and writing of a Phase I water quality report. The Klamath Network discussed the situation and decided, based upon the existing network expertise and time available, to produce the Phase I report in-house, with technical assistance from the parks. The Network did not identify the need to hold a separate water quality scoping and/or vital signs meetings to gather park information, but incorporated the WQ into the Aquatic Group of the network’s vital signs workshop. A follow up meeting is planned for early FY 05 to focus in on water quality associated vital signs.

## B. General Issues Outlined in Scoping Process

### *Water Quality Issues*

Several vital signs will be used to detect improvements (or lack thereof) in water quality related to state 303(d) streams. They will also enable park managers to report on progress towards GPRA goal 1.a4 – that the parks have unimpaired water quality. These vital signs include:

- **Watershed budgets.** A compilation of water, nutrient, sediment, and chemical inputs and outputs for a particular watershed. These budgets are variable depending on the study area; however, most monitor the concentration of major ions and isotopes, stream flow, groundwater hydrology, and continuous temperature. Watershed budgets are one method for monitoring water quality.
- **Continuous water temperature.** Because temporal variation in temperature can be significant, intermittent temperature monitoring (stations) can be problematic. Thus, use of continuous recording devices is a preferred means of eliminating time-associated sampling problems. All temperature measurements should be made and reported in units of degrees Celsius (°C), and reported to the nearest 0.2°C when using a thermistor thermometer and to the nearest 0.5°C when using a liquid-in-liquid thermometer.
- **Groundwater quantity and quality.** This refers to the groundwater level and chemistry (including contamination). This information can be obtained through purging and sampling of groundwater wells, including data such as groundwater level and volume, pH, temperature, conductivity, and trace organic compounds and metals.
- **Reservoir elevation.** Lakes that are hydrologically managed will have fluctuating water levels that can potentially affect lake food webs and ecosystem function and, therefore, need to be monitored for elevation changes, reservoir storage, inflow, and outflow.
- **River invertebrate assemblages.** The composition of invertebrate assemblages can indicate water quality and may change in response to the presence of exotic species, sedimentation, nutrient load, predator population change, and/or climate change. Sampling can occur according to two methods: comparing measured assemblage structure with species that may be indicative of water quality (e.g., Stribling et al. 1998), or using multivariate approaches to estimate predicted invertebrate assemblages that can be compared to measured assemblage structure.
- **Springs and seeps distribution and hydrology.** This includes the location and the volume, duration, and seasonality of flow of springs and seeps locations. This vital sign is quantified by calculating the physical/geometric measurements (maximum, minimum, and average depth, length, and width of the surface water) and discharge (flow duration, peak flows, and flow quantity) at each spring or seep.

- **Stream flow.** Also known as stream discharge, stream flow is the measure of the flow of water in a stream at a specific time, including (1) routing mechanisms in a watershed and water quality at that time, and (2) land-use activities, point-source discharges, and natural sources. Stream discharge (Q) is defined as the unit volume of water passing a given point on a stream or river over a given time. It is typically expressed in cubic feet per second (cfs) or cubic meters per second (cms), and is based on the equation:  $Q = A \cdot V$ , where A is the cross-sectional area of the stream at the measurement point and V is the average velocity of water at that point.
- **Water chemistry.** Information from monitoring water chemistry is used to evaluate stream condition with respect to stressors such as atmospheric deposition, nutrient enrichment, and other inorganic contaminants. The following parameters and ions are usually monitored: alkalinity, ammonia, bicarbonate, carbonate, calcium, chloride, fluoride, trace metals, nitrate, pH, potassium, silica, sodium, sulfate, total dissolved solids, total suspended solids, and total nitrogen and phosphorous (reported in micro or milligrams per liter). Concurrent discharge measurements allow data to be presented as mass flows (e.g., g/hr).
- **Algal species composition and biomass.** Algal species composition refers to the kinds of species present in a body of water, while algal biomass is the combined mass of these species. Certain species can indicate changes in the water column, such as increased nutrient input or water temperature. Algal composition is measured by examining algal assemblages, while algal biomass can be measured using chlorophyll A concentrations or Secchi disk measurements (for water clarity).
- ***Escherichia coli* (E. coli).** *E. coli* is one type of fecal bacteria that may cause gastrointestinal illness in swimmers, based on the density of the indicator organism in bathing waters. The EPA requires that no more than a geometric mean of 126 *E. coli* per 100 ml of fresh water (or 260 *E. coli* per 100 ml for any single sample) should be present to protect people from gastrointestinal illness (depending upon the beneficial use of the water).
- **Exotic aquatic community structure and composition.** These include the number of exotic fish species (e.g., kokanee salmon in Crater Lake), as well as invertebrates (e.g., the New Zealand mud snail), that are causes of concern in park aquatic ecosystems. Monitoring the distribution (geographical location), abundance (number at each sampling location), and spread of the species will allow managers to understand the environmental consequences of these communities.
- **Native aquatic community structure, composition, stability and genetic integrity.** Referring to overall health of the fish communities in water bodies of interest. To measure native aquatic health, species richness, and composition metrics, trophic composition metrics, fish abundance, condition metrics, and genetic purity analysis must be performed.
- **Atmospheric deposition of nitrogen, sulfur, and all major anions and cations (including wet and dry deposition):** Atmospheric deposition is the process

whereby precipitation (rain, snow, fog), particles, aerosols, and gases move from the atmosphere to the earth's surface. This vital sign is quantified by measuring snowpack chemistry and direct measurements of wet (NADP/NTN) and dry (CASTNet) deposition. The Klamath Network parks all experience fire effects, either as wildfire or control burns. Fire has the ability to increase atmospheric deposition and reduce visibility.

- **Basic climatological measurements:** Basic climatological measurements include: temperature (maximum, minimum, and average), precipitation, relative humidity, wind, surface pressure and snow cover, depth and water equivalent. The following are recommended standard metrics for these climatological variables: air temperature (°C), surface wind (m/s), and atmospheric humidity/water vapor (in percent, mixing ratio in g H<sub>2</sub>O/kg-air, or concentration in g H<sub>2</sub>O/m<sup>3</sup>), surface pressure (hectopascals [hPa] or millibars [mb]), snow cover and depth (water equivalent per km<sup>2</sup> and/or percent of area for cover and mm/cm for depth).
- **Stream sediment transport.** Sediment data, both suspended and channel bed, is necessary to evaluate sediment yield with respect to background environmental conditions (geology, soils, climate, runoff, topography, ground cover, and size of drainage area), historic and current land uses, and erosion and deposition in channel systems. Additionally, the understanding of the temporal distribution of sediment concentration, size characteristics, and transport rates is crucial to the management of instream aquatic communities and riparian ecosystems. Standardized sediment sampling methods and the frequency of collection will be dictated by the hydrologic and sediment characteristics of the water body to be sampled in the Klamath Network (they will vary greatly), the required accuracy of the data, the funds available, and the proposed use of those data collected.

### C. Lists of monitoring questions and vital signs.

Water quality parameters were one important element of monitoring questions and vital signs in our May 2004 vital signs scoping meeting. Full details of that meeting and its chief outcomes are summarized in Appendix G. Here, we present a list of monitoring questions and candidate vital signs for water quality (Table 4).

Table 4. Monitoring question and potential vital signs for national framework, level 1, Water Quality category.

Subcategories	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments (June 04 SAC)
Hydrology	What is the effusion rate of groundwater into the surface environment? (geothermal)	Groundwater dynamics (discharge)	Process	
	What are ground water changes?	aquifers (depth volume variability)	Aquatic	
		hyporheic zones	Aquatic	
	What is happening with the hydrological cycle?		Terrestrial.	
	What are trends in soil moisture across vegetation habitats.	evapotranspiration	Terrestrial.	
	Hydrothermal output into aquatic system	aquatic chemistry	Process	
	seepage	groundwater (discharge composition)	SAC	
	water flow (water supply)	Water flow	SAC	
		water supply	Process, Aquatic	
Subterranean	How are changes in water and ice quantity, rates, and quality affecting erosion, deposition, and biota?	Water Flow (quantity)	Cave, Aquatic	
		Distribution (Water/Ice Budget)	Cave, Aquatic	
		Crustaceans and worms	Cave, Aquatic	
		Water Chemistry (quality)	Cave, Aquatic	
		Microorganisms	Cave	

Subcategories	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments (June 04 SAC)
Water Quality	Point source pollution	pollutants (inorganic)	Process, Marine	
	Non point source pollution	pollutants (organic)	Marine	
		water chemistry	Process, Aquatic	
		nutrient levels	Whiskeytown	
	Watercraft emissions	Hydrocarbon deposition	SAC	
	Aquatic biological communities	aquatic organisms	Aquatic	benthic algae, canopy cover, macroinvertebrates, fresh water mussels, substrate
		water (physical)	Aquatic	
	When and how much water is occurring in ephemeral systems and can we detect a change over time?	vernal pools	Terrestrial.	
		ephemeral streams	SAC	
		littoral ponds (Crater Lake)	SAC	
		Seasonal wet meadows (Lassen Volcanic)	SAC	
		snow melt beds	SAC	
	Is the size and distribution of perennial water bodies (streams, lakes, snow fields, springs, wetlands) changing over time?	distribution of water bodies	Aquatic	
	What are the extent of material, biological, and chemical pollution in marine ecosystem.		MARINE	

Subcategories	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments (June 04 SAC)
	What are status and trends in marine trash (material trash)	seabirds	MARINE	Percent of beached marine seabird carcasses with attached debris
	What are status and trends in the following:	marine mammals		percent of beached marine mammal carcasses with attached debris
	-terrestrial source pollution in intertidal		MARINE	
	-oil	oil, seabirds	MARINE	Presence/absence of oiled beach marine seabird carcasses
		marine mammals	MARINE	Presence/absence of oiled beach marine mammal carcasses
	-river discharged pollution	pollutants	MARINE	Similar water quality testing as done by State Water Quality Control Board
	-salinity	surface salinity	MARINE	Annual and seasonal variations in open ocean and estuary
	-turbidity/clarity	turbidity	MARINE, VSA	NTUs, Light penetration in estuary, intertidal and subtidal zones, extent of turbid river plumes

Subcategories	Monitoring Question	Vital Sign (Klamath)	Question Identified by	Comments (June 04 SAC)
	Sea surface/subsurface Temperature	Sea surface/subsurface Temperature	MARINE	Annual and seasonal variations of water samples in open ocean
	Dissolved oxygen	Dissolved oxygen	REDW MARINE	Annual and seasonal water sample variations in estuary
	What are effects of upstream management on estuaries (daMarine, flow regulation, water quality)?	water temp. (estuary)	MARINE	
		Chlorophyll A	MARINE	Annual and seasonal variations of water samples in estuary
		Coliform bacteria	MARINE	Annual and seasonal variations of water samples in estuary
		Forest Herbicides	MARINE	Annual and seasonal variations of water samples in estuary
	What are effects of upstream management on estuaries (land use)?	dissolved oxygen (estuary)	MARINE	Annual and seasonal variations in estuary

## 1.8 REFERENCES CITED

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